

# FOOD HABITS OF BAIT-CAUGHT SKIPJACK TUNA, *KATSUWONUS PELAMIS*, FROM THE SOUTHWESTERN ATLANTIC OCEAN

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## ABSTRACT

Stomach contents of skipjack tuna captured in 1981-82 by live pole-and-line vessels off the southern coast of Brazil were analyzed for the presence of larval and juvenile skipjack tuna. The percentage frequency of occurrence, percent number, and percent volume were evaluated. Of the 1,041 stomachs that were examined for food, 436 were empty. The mean volume of food in all stomachs analyzed was 36.9 mL, of which 18.9 mL was bait and 18.0 mL was prey.

The gonostomatid *Mawrolicus muelleri* and the euphausiid *Euphausia similis* were the principal foods. Other important foods were the chub mackerel, *Scomber japonicus*; the frigate tuna, *Auxis thazard*; gemmylids; trichiurids; and carangids. In the study area, adult skipjack tuna were not found to feed on their young.

Kruskall-Wallis nonparametric one-way analysis of variance was used to test for differences in the mean volumetric ratios of food items in relation to skipjack size. The percentage of *E. similis* in the diet was found to decrease, while the proportion of *M. muelleri* was found to increase with increasing skipjack size. Seasonal variations in the diet were also examined and discussed.

Apparently the anatomy of their gill raker apparatus allows skipjack to ingest a wide variety of prey types above a minimum size. These variations in the food can be attributed to the number and size of the prey species in an area.

A Brazilian skipjack pole-and-line fishery has been developing in the Rio de Janeiro area since 1979 (Fig. 1). Because skipjack tuna, *Katsuwonus pelamis*, is one of the major tuna species harvested at maximum sustainable yield in the tropical and subtropical oceans (Kearny 1976; Evans et al. 1981), estimation of the fishery potential requires information on the distribution and concentration of its spawning stock. One technique used to determine the existence of a spawning stock is to quantify the distribution of its larvae. Obviously, the presence of large numbers of larvae would indicate a spawning stock occupies an area.

Knowledge of the distribution and abundance of juvenile skipjack tuna is limited. Occasionally, specimens have been found in experimental plankton hauls or in the stomachs of apex predators (Kearny 1976). From ichthyoplankton surveys, Matsuura (1982) and Nishikawa et al. (1978) reported larvae in warm tropical waters north of the study area (Fig. 1), and juvenile skipjack tuna have been found in the stomachs of adult skipjack tuna captured off west Africa and in the Caribbean (Suarez-Caabro and

Duarte-Bello 1961; Klawe 1961; Dragovich 1970; Dragovich and Potthoff 1972). Their occurrence in the diet of central and south Pacific skipjack tuna caught by pole-and-line has been used to deduce their distribution and abundance (Waldron and King 1963; Nakamura 1965; Argue et al. 1983).

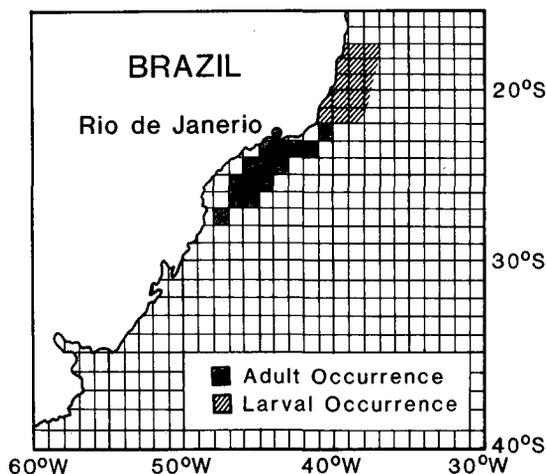


FIGURE 1. - Solid area indicates fishing localities from where skipjack tuna stomachs were obtained. Hatched area shows larval occurrence (Matsuura 1982).

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Dragovich (1969) reviewed existing information on the food habits of Atlantic skipjack tuna. Since that time food habits have also been reported in studies by Dragovich (1970) and Dragovich and Potthoff (1972) for skipjack from the East and West Atlantic and by Batts (1972) for skipjack in North Carolina waters. Zavala-Camin (1981) examined predator-prey interactions of fishes, including skipjack captured north of the area in this study.

The primary objective of this study was to discover if skipjack tuna feed upon their young. The presence of juveniles in bait-caught skipjack stomachs would verify the study area as a spawning-rearing ground. Knowledge of the prey and their relative importance also contributes to the understanding of prey-predator interactions, which affect population distributions and fluctuations.

## MATERIALS AND METHODS

Stomach samples for this study were collected on a monthly basis from October 1981 to December 1982 from skipjack tuna caught off Rio de Janeiro (Fig. 1). National Marine Fisheries Service (NMFS) personnel collected stomachs from frozen fish transhipped to Puerto Rico, and Superintendencia do Desenvolvimento da Pesca (SUPEDE) personnel sampled fish landed locally in Rio de Janeiro. Fish from the Puerto Rican source were caught within 1 mo prior to sampling; fish from the Brazilian source were sampled 3 to 5 d after the recorded catch date. The sampling design required collecting about 15 stomachs from each 10 cm length group, measured to the nearest cm per month. However, the number of stomachs collected was dependent on the catch-size distribution. Once the stomach was removed from the fish, it was preserved in 10% buffered Formalin<sup>2</sup> and shipped to the Southwest Fisheries Center (SWFC) for analysis.

Stomachs were examined from 1,041 fish between 44 and 81 cm fork length. In the laboratory each stomach was opened. The volume of the food bolus was measured, and the contents were identified to the lowest possible taxon. The taxonomic groupings were then measured by volumetric displacement, and the individuals counted. Whole undigested fish were identified by comparing external characters with those described in published keys or with identified museum specimens from Scripps Institution of Oceanography, La Jolla, CA. Digested animals, particularly juvenile scombrids, were identified by verte-

bral, gill raker, and fin ray counts, as well as other skeletal characteristics, described by Potthoff and Richards (1970), Miller and Jorgenson (1973), and other published keys. Cephalopods were identified by comparing beak characters with published illustrations, descriptions, and keys (see Wolff 1981). Crustaceans and other invertebrates were identified by specialists from Scripps Institution of Oceanography and SWFC.

The occurrence of bait in the stomachs may have biased the relative importance of fish in the diet. The bait primarily consisted of *Sardinella brasiliensis*, *Harengula jaguana*, and *Engraulis anchoita*; however, other fish families may have been included in the captured bait. The sardines were readily identifiable from their external characters and usually were undigested. The anchovies, in contrast, were often quite digested, creating difficulties in identification. Gary Nelson<sup>3</sup> nevertheless was able to verify these fish as *Engraulis anchoita*. Although the least digested item in the stomach was usually the last meal (bait), stomachs were removed from a few days to 1 mo after capture, and presumably postmortem digestion occurred. As a result, the degree of digestion was not a reliable indication of distinguishing bait from natural prey. The time required for complete gastric evacuation of smelt fed to skipjack tuna is estimated to be 12 h (Magnuson 1969). Although the bait was captured in nets from bays and estuaries (Rinaldo<sup>4</sup>), Matsuura et al. (1978, 1981) have confirmed that a spawning stock of *E. anchoita* does exist in waters inhabited by skipjack tuna. It is unlikely that the sardines served as prey for skipjack. However, I could not distinguish between *E. anchoita* consumed as natural food and as bait. Therefore, although these species were considered bait, some may have been ingested as natural food. Bait was not considered prey, and stomachs containing only these species were treated as empty.

Two methods of analysis were employed to rank the food items in terms of availability and importance to the skipjack tuna:

1) An index of relative importance (*IRI*) was calculated for each prey type in terms of numbers, volumes, and frequencies (Pinkas et al. 1971):

$$IRI = (N + V) F$$

<sup>3</sup>G. J. Nelson, Department of Ichthyology, American Museum of Natural History, New York, NY 10024, pers. commun., May 1982.

<sup>4</sup>R. R. Rinaldo, Southwest Fisheries Center La Jolla Laboratory, National Marine Fisheries Service, NOAA, P.O. Box 271, La Jolla, CA 92038, pers. commun., June 1982.

<sup>2</sup>Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

where  $N$  = numerical percentage  
 $V$  = volumetric percentage  
 $F$  = frequency of occurrence percentage.

2) The mean volumetric ratio measurement (*MVRM*) was used to illustrate the biomass importance of prey items without the numeric exaggeration implicit in the *IRI* (John Hedgepeth<sup>5</sup>). The *MVRM* was calculated from the volumetric analysis of individual stomachs with each prey item contributing to the total stomach volume. *MVRM* for each food type is expressed as

$$MVRM = \bar{r}_j \times 100 = \text{mean volumetric percentage of prey } j \text{ to the total volume of } n \text{ stomachs}$$

where  $N$  = number of stomachs in a given strata  
 $V_{ij}$  = volume of prey type  $j$  in stomach  $i$

$$V_i = \sum_{j=1}^6 V_{ij} = \text{total volume of stomach } i$$

$$r_{ij} = \frac{V_{ij}}{V_i} = \text{ratio of prey } j \text{ to the total volume of stomach } i$$

$$\bar{r}_j = \frac{\sum_{i=1}^n r_{ij}}{n} = \text{mean volumetric ratio of prey } j \text{ to the total volume of } n \text{ stomachs.}$$

Both the *IRI* and the *MVRM*, which examine different aspects of the diet, were used to evaluate seasonal variations in skipjack tuna food habits. The *IRI* presents a biased estimate caused by the numerical percentage; the relative importance of small numerous organisms, like euphausiids, is exaggerated in the *IRI* because of their high numbers, when actually they may represent the same food value as a few large fish. The *MVRM* is an expression of frequency of occurrence and volume without a numeric bias, but does not provide any information on prey abundance. The *IRI* contains information on the availability of the prey in the environment in terms of numbers, while the *MVRM* provides an indication of its energetic importance to the fish.

The *MVRMs* were stratified by fish length and

annual quarter (Fig. 2), and tested with the Kruskal-Wallis nonparametric one-way analysis of variance to evaluate differences in diet with changes in size.

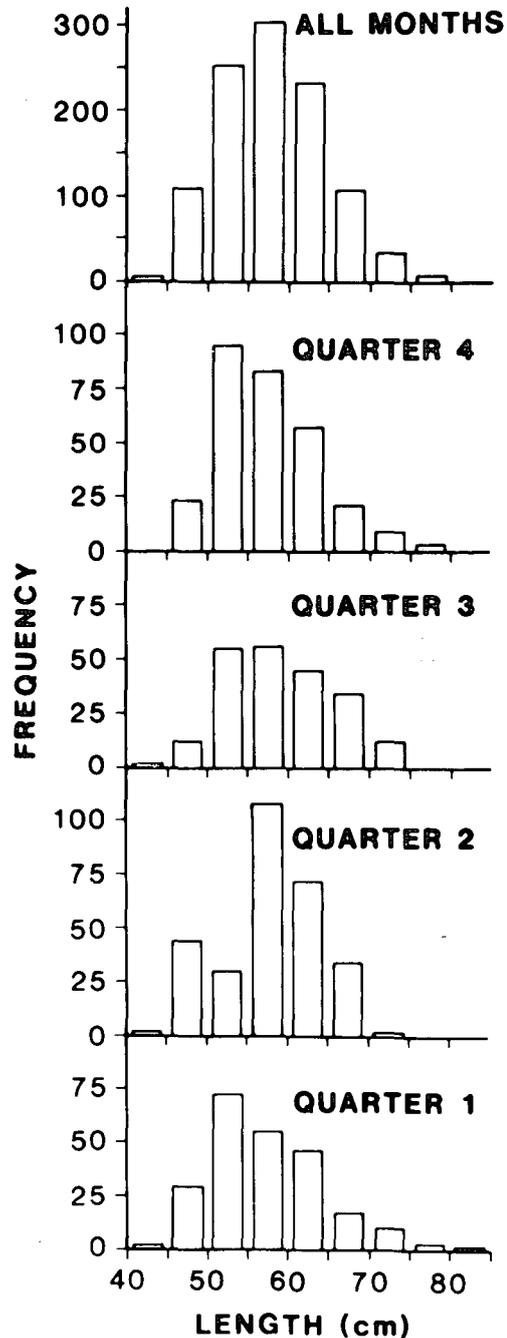


FIGURE 2.—Length-frequency distribution of skipjack tuna from which stomachs were collected.

<sup>5</sup>J. B. Hedgepeth, Southwest Fisheries Center La Jolla Laboratory, National Marine Fisheries Service, NOAA, P.O. Box 271, La Jolla, CA 92038, pers. commun., April 1982.

RESULTS

Food Composition

Of the 1,041 stomachs that were examined, 436 were empty. The mean volume of food in all stomachs examined was 36.9 mL, of which 18.9 mL was bait and 18.0 mL was prey. A complete list of the stomach contents in terms of numbers, volume, and frequency is presented in Appendix Table 1. No larval or juvenile skipjack were found in the stomach contents. Overall contributions of each category are presented in Figure 3.

In terms of the *MVRM*, the gonostomatid *Maurolicus muelleri* was the major prey item (*MVRM* = 26.7%). The euphausiid *Euphausia similis*, with the highest *IRI*, was also important (*IRI* = 1,998). These items were major constituents of the diet throughout the year. Other important fishes in terms of both the

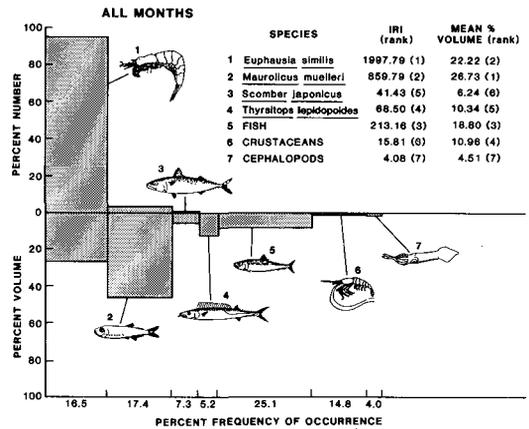


FIGURE 3.—Index of relative importance (IRI) plots for selected food items of skipjack tuna caught during 1982. The food categories are ranked in terms of IRI and *MVRM*.

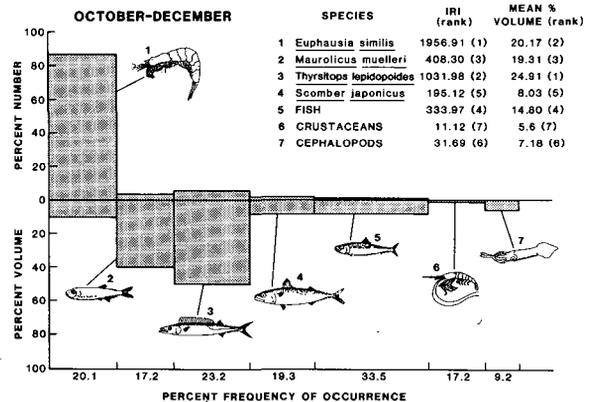
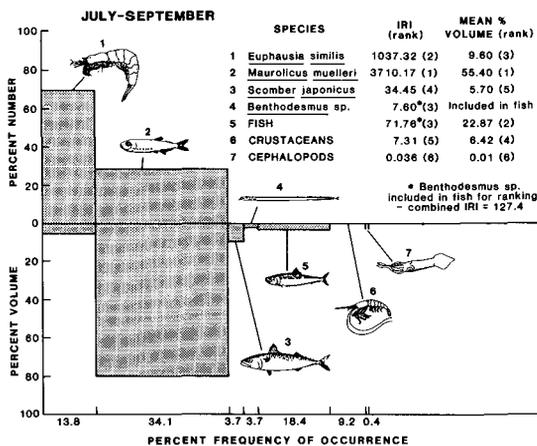
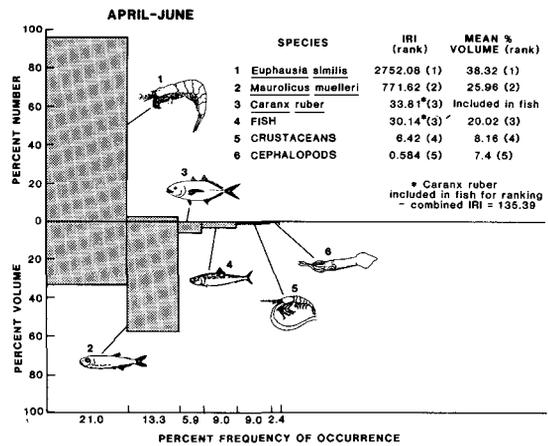
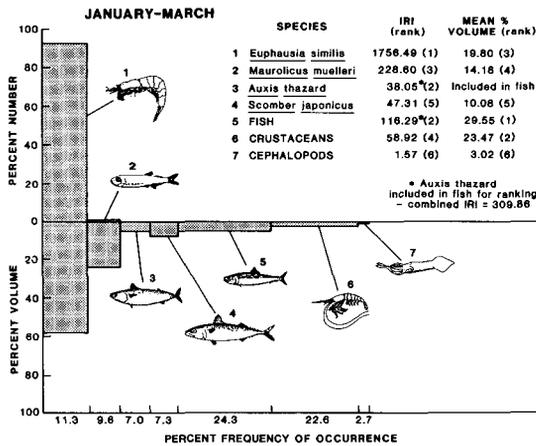


FIGURE 4.—Index of relative importance (IRI) plots for selected food items of skipjack tuna. The complete data are divided into four 3-mo quarters (I-IV). The food categories are ranked in terms of IRI and mean percent volume.

*IRI* and *MVRM* were chub mackerel, *Scomber japonicus*, and *Thyrsitops lepidopoides*<sup>6</sup> (Fig. 3). Crustaceans other than *E. similis* occurred frequently in the stomachs ( $F = 22.6\%$ ), but as a relatively low percentage of the total volume ( $V = 2.0\%$ ). Cephalopods were usually insignificant in the diet (see below). Pteropods, siphonophores, beetles, rocks, and unidentified materials were the constituents of the miscellaneous category (App. Table 1).

### Seasonal Variations

The data were divided into four quarters: January-March 1982 (I), April-June 1982 (II), July-September 1982 (III), October-December 1981 and 1982 (IV). The results (App. Tables 2-6) are illustrated in Figures 4 and 5 both with the *IRI* and the *MVRM* of

dominant food items in each quarter. Note that items important in one quarter may be negligible or absent in another. When evaluated in terms of *MVRM*, the prey ranks sometimes did not coincide with those determined by the *IRI* (Figs. 4, 5). Based on the *IRI*, *E. similis* was the dominant food in the first quarter, followed by other fish and *M. muelleri* (Fig. 4). According to the *MVRM*, other fishes, other crustaceans, and *E. similis* were ranked first, second, and third in importance, respectively. The importance of *E. similis* in this quarter based on the *IRI* was exaggerated by their high frequencies of occurrence. *Scomber japonicus* and frigate tuna, *Auxis thazard*, were secondary in importance to *M. muelleri* as the main fish species consumed.

The rankings of the food categories in the second quarter were the same for both the *IRI* and the *MVRM* (Fig. 4). *Euphausia similis* and *M. muelleri* were the dominant food items, followed by *Caranx ruber*.

<sup>6</sup>Identified by Y. Matsuura, Universidade de São Paulo, Instituto Oceanográfico, São Paulo, Brazil, October 1984.

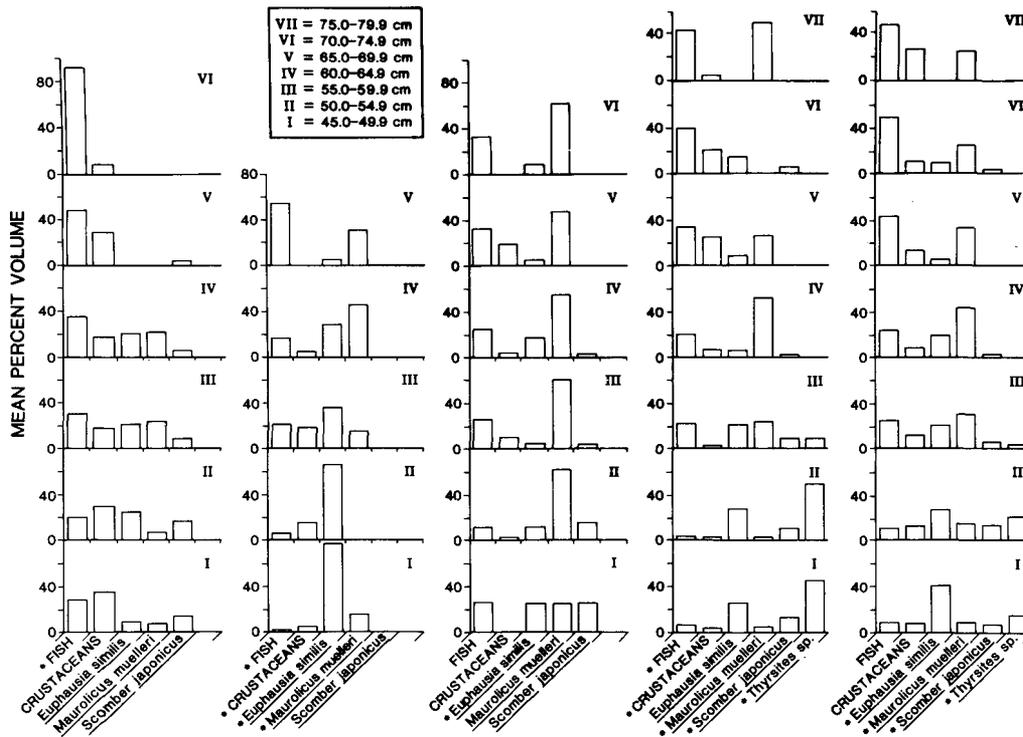


FIGURE 5. - Relative importance based on mean volumetric ratio of selected food items for skipjack tuna grouped by length for each quarter (I-IV) and all months. \* indicates a significant difference ( $P < 0.05$ ) in the mean percent volume of that food item by length when tested with the Kruskal-Wallis nonparametric one-way analysis of variance.

The principal food item in the third quarter based on both measurements was *M. muelleri* (Fig. 4). The ranks for the other items did not correspond. *Euphausia similis* was second in importance according to the IRI, but ranked third next to other fish based on the MVRM. *Scomber japonicus* and *Benthodesmus* sp. were the predominant species consumed in the fish category.

The IRI and MVRM ranks in the fourth quarter corresponded with the exception of the principal prey type (Fig. 4). Again, *E. similis* ranked first according to the IRI, but *Thyrssitops lepidopoides* was the primary food item based on the MVRM. Cephalopods, mainly *Argonauta* sp., were consumed in significant proportions in this quarter (IRI = 31.7, MVRM = 7.2%).

In summary, *M. muelleri* and *E. similis* predominated in the skipjack tuna diet during all quarters (Fig. 3). With the exception of the second quarter, *S. japonicus* was an important food item. *Benthodesmus* sp., *C. ruber*, *A. thazard*, as well as the cephalopod, *Argonauta* sp., also proved important in specific quarters. The importance of *T. lepidopoides* in Figure 3 was exaggerated by its predominance in the fourth quarter.

### Variations with Size

As might be expected, basic dietary changes occur as the skipjack tuna grow. Nakamura (1965), Alverson (1963), Batts (1972), Dragovich and Potthoff (1972), and Wilson (1982) observed a decrease in the relative importance of crustaceans and an increasing importance of fish in the diet, as the skipjack size increased.

To evaluate the relationship between size and food habits, the skipjack were arbitrarily divided into seven 5 cm groups (Fig. 2). For each prey category the MVRMs were stratified by size group and quarter (App. Tables 6-10, Fig. 5). Trends reported in the results for length groups > 70 cm may not represent feeding habits of skipjack tuna from the study area because the sample sizes were too small (Fig. 2, App. Table 6).

There were no significant differences ( $P < 0.05$ ) in diet and size in the first quarter except in the amount of other fish consumed (Fig. 5, App. Table 7). The MVRM of this category increased from 28.7% in skipjack 45.0-49.9 cm to 91.7% in fish 75.0-79.9 cm.

In the second quarter the proportions of other fish, other crustaceans, *E. similis*, and *M. muelleri* significantly changed with size (Fig. 5, App. Table 8). The larger skipjack tuna ate more fish (MVRM = 1.7% in the 45.0-49.9 cm size class to MVRM = 54.1% in the

75.0-79.9 cm size class) and more *M. muelleri* (MVRM = 15.4% to MVRM = 30.3%) than the smaller skipjack. As their size increased, skipjack decreased their consumption of *E. similis* from MVRM = 76.9% to MVRM = 4.5%. There was a significant difference between size classes ( $P < 0.05$ ) in the MVRM of other crustaceans in the diet, but this difference seemed uncorrelated to increases in size.

In the third quarter there were no significant differences in the diet with increasing size except that the MVRM of *E. similis* decreased from 25.0% to 8.0% (Fig. 5, App. Table 9).

*Thyrssitops lepidopoides* was eaten by the smaller skipjack (45-59.9 cm) only in the fourth quarter (Fig. 5, App. Table 10). Although there were significant differences ( $P < 0.05$ ) in the diets between the seven size groups during this period, these differences again seemed unrelated to increasing size.

In summary, when the data on *T. lepidopoides* were included with the rest of the fish data, there were no significant differences between size groups in the proportions of other fish consumed throughout the year (Fig. 5, App. Table 6). The MVRM of *E. similis* in the diet decreased from 42.5% in skipjack tuna 45.0-49.9 cm to 0.0% in skipjack 75.0-79.9 cm. There were significant differences in the percentages of *M. muelleri* and *S. japonicus* between the size classes. There were no significant differences in the MVRM of other crustaceans with changes in size.

As reported in the studies of the food habits of skipjack tuna referred to above, the stomach contents of skipjack from this area indicated the basic dietary changes associated with increasing size: a significant decrease in the proportion of *E. similis*, the predominant crustacean prey, and an increase in proportion of *M. muelleri*, the predominant fish prey.

### DISCUSSION

Several studies have reported that skipjack tuna feed predominantly on euphausiids and gonostomatids. Dragovich and Potthoff (1972) reported that the gonostomatid *Vinciguerria nimbaria* contributed 44.7% by volume to the diet of skipjack tuna from the Gulf of Guinea. Zavala-Camin (1981) reported *M. muelleri* and euphausiids as dominant food items in 36 stomachs of skipjack caught off Brazil. Alverson (1963) reported skipjack tuna captured in the eastern tropical Pacific fed primarily on euphausiids (47% by volume, in 37% of the stomachs), followed in importance by the gonostomatid *Vinciguerria lucretia* (10% by volume). The abundance of euphausiids in

the stomachs of skipjack, compared with larger scombrids, may be a result of smaller gill raker gaps in skipjack (Magnuson and Heitz 1971).

The importance of other fishes as food for western Atlantic skipjack tuna observed in this study has been previously reported. Dragovich (1970) found a predominance of fish in the stomachs of skipjack caught off the eastern United States and the Caribbean. Suarez-Caabro and Duarte-Bello (1961) found that fishes constituted 75% of the total volume, followed by squid (23%) and crustaceans (2%), in the stomachs of Cuban skipjack. Zavala-Camin (1981) observed that fish constituted 38.9%, crustaceans 22.2%, and mollusks 2.8% of the total stomach volume of Brazilian skipjack.

## CONCLUSIONS

The multiplicity of prey found in this as well as other studies indicates that tunas are perhaps non-selective feeders, and stomach contents are probably determined by prey availability (Hotta and Ogawa 1955; Alverson 1963; Batts 1972; Perrin et al. 1973; Argue et al. 1983). Therefore, if the larval and juvenile skipjack were available in significant numbers, then one would expect them to occur in the diet of the adults.

Their absence in the diet was caused by two possible results. First, the young remained among the unidentified portion of the stomach contents; however, skipjack tuna have distinctive vertebral characteristics which were probably not discounted in the analysis (Potthoff and Richards 1970). Second, the adults did not spawn in the study area. Young skipjack should be found in the stomach contents of spawning adults (Argue et al. 1983). Goldberg and Au<sup>7</sup> found no evidence of spawning in skipjack collected from the Brazilian fishery. These results are consistent with the absence of larval and juvenile skipjack in the diet of the adults in this study.

The southernmost distribution boundary for larval skipjack tuna is the 24°C surface isotherm (Argue et al. 1983). Matsuura (1982) found no larval skipjack in ichthyoplankton surveys south of lat. 21°S in this area, where temperatures range from 21° to 24°C (Evans et al. 1981).

<sup>7</sup>Goldberg, S. R., and D. W. K. Au. 1983. The spawning schedule of skipjack tuna from southeastern Brazil as determined from histological examinations of ovaries, with notes on spawning in the Caribbean. Prepared for the International Skipjack Year Program conference of the International Commission for the Conservation of Atlantic Tunas, June 21-25, 1983, Tenerife, Canary Islands, Spain, 31 p. Manuscript in preparation; Department of Biology, Whittier College, Whittier, CA 90608.

These results are consonant with those of Argue et al. (1983); juvenile skipjack tuna were absent from samples of adult stomachs taken in subtropical south Pacific waters. The adult skipjack in this investigation did not feed on their young. The absence of cannibalism suggests that larvae and juveniles were not significantly abundant to serve as forage of the adults, and therefore probably do not occur in this cooler southern water.

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## APPENDIX

APPENDIX TABLE 1.—List of prey items and other ingested materials found in the stomachs of 1,041 skipjack tuna caught off southern Brazil, from October 1981 to December 1982.

Prey items	Numbers		Volume		Occurrence	
	No.	%	mL	%	No.	%
Crustacea						
Stomatopoda	12.0	0.003	4.5	0.024	6.0	0.576
Mysidacea						
Eucopiidae	220.0	0.057	42.4	0.226	22.0	2.113
Lophogastridae	24.0	0.006	1.7	0.009	3.0	0.288
Isopoda	1.0	0.000	0.1	0.001	1.0	0.096
Flabellifera	7.0	0.002	2.1	0.011	7.0	0.672
Amphipoda	22.0	0.006	1.5	0.008	2.0	0.192
Gammaridea	16.0	0.004	5.1	0.027	10.0	0.961
Euphausiidae	139.0	0.036	3.9	0.021	15.0	1.441
<i>Euphausia</i> sp.	50.0	0.013	0.6	0.003	1.0	0.096
<i>Euphausia similis</i>	368,632.0	94.785	4,895.3	26.122	172.0	16.523
<i>Stylocheiron</i> sp.	1.0	0.000	0.3	0.002	1.0	0.096
Caridea	3.0	0.001	2.3	0.012	3.0	0.288
Macrura						
Scyllaridae	1.0	0.000	0.2	0.001	1.0	0.096
Unid. Phyllosoma larvae	1.0	0.000	0.1	0.001	1.0	0.096

APPENDIX TABLE 1.—Continued.

Prey items	Numbers		Volume		Occurrence	
	No.	%	mL	%	No.	%
Brachyura	5.0	0.001	0.7	0.004	1.0	0.096
Portunidae	1.0	0.000	0.1	0.001	1.0	0.096
Unid. megalops	102.0	0.026	32.0	0.171	27.0	2.594
Unid. zoea	555.0	0.143	30.2	0.161	24.0	2.305
Unid. Decapoda	7.0	0.002	0.6	0.003	2.0	0.192
Unid. Crustacea	96.0	0.025	11.0	0.059	26.0	2.498
Mollusca						
Gastropoda	1.0	0.000	0.1	0.001	1.0	0.096
<i>Cavolina</i> sp.	101.0	0.026	6.0	0.032	7.0	0.672
Cephalopoda						
Teuthoidea	4.0	0.001	26.0	0.139	4.0	0.384
Thysanoteuthidae	2.0	0.001	10.0	0.053	1.0	0.096
Ommastrephidae	35.0	0.009	55.1	0.294	18.0	1.729
Loliginidae	2.0	0.001	10.5	0.056	2.0	0.192
Histiotteuthidae	1.0	0.000	1.0	0.005	1.0	0.096
Onychoteuthidae	13.0	0.003	6.0	0.032	2.0	0.192
Octopoda						
Argonautidae						
<i>Argonauta</i> sp.	20.0	0.005	75.9	0.405	11.0	1.057
Unid. Cephalopoda	4.0	0.001	1.3	0.007	3.0	0.288
Insecta						
Coleoptera	2.0	0.001	2.0	0.011	2.0	0.192
Siphonophora	1.0	0.000	0.9	0.005	1.0	0.096
Algalmidiae	8.0	0.002	6.6	0.035	8.0	0.768
Pisces						
Gonostomatidae						
<i>Maurolicus muelleri</i>	13,438.0	3.455	8,619.3	45.994	181.0	17.387
Synodontidae	8.0	0.002	16.0	0.085	3.0	0.288
Paralepididae	1.0	0.000	0.5	0.003	1.0	0.096
Myctophidae	43.0	0.011	62.3	0.332	5.0	0.480
Exocoetidae	2.0	0.001	2.0	0.011	2.0	0.192
<i>Exocoetus volitans</i>	1.0	0.000	56.0	0.299	1.0	0.096
Scomberesocidae						
<i>Scomberesox saurus</i>	8.0	0.002	105.0	0.560	6.0	0.576
Belonidae	2.0	0.001	5.0	0.027	2.0	0.192
Macrorhamphosidae	5.0	0.001	6.9	0.037	4.0	0.384
Sygnathidae	1.0	0.000	1.0	0.005	1.0	0.096
Holocentridae	3.0	0.001	4.0	0.021	1.0	0.096
<i>Holocentrus</i> sp.	3.0	0.001	9.0	0.048	1.0	0.096
Carangidae	1.0	0.000	1.0	0.005	1.0	0.096
<i>Selene vomer</i>	8.0	0.002	17.0	0.091	8.0	0.768
<i>Decapterus punctatus</i>	2.0	0.001	46.0	0.245	2.0	0.192
<i>Caranx ruber</i>	70.0	0.018	360.0	1.921	17.0	1.633
Mullidae	11.0	0.003	25.0	0.133	6.0	0.576
Scombridae	16.0	0.004	2.5	0.013	3.0	0.288
<i>Auxis thazard</i>	474.0	0.122	223.7	1.194	23.0	2.209
<i>Scomber japonicus</i>	1,474.0	0.379	978.7	5.223	77.0	7.397
<i>Sarda sarda</i>	81.0	0.021	127.0	0.678	8.0	0.768
Gempylidae	176.0	0.045	100.7	0.537	20.0	1.921
<i>Thyrstitops lepidopoides</i>	2,617.0	0.673	2,348.4	12.532	54.0	5.187
Trichiuridae	11.0	0.003	12.0	0.064	4.0	0.384
<i>Benthodesmus</i> sp.	19.0	0.005	80.9	0.432	8.0	0.768
Unid. Perciforms	24.0	0.006	63.7	0.340	16.0	1.537
Balistidae	1.0	0.000	5.0	0.027	1.0	0.096
Monacanthidae	27.0	0.007	19.8	0.106	19.0	1.825
Ostraciidae	1.0	0.000	0.5	0.003	1.0	0.096
Mollidae						
<i>Ranzania</i> sp.	3.0	0.001	13.0	0.069	1.0	0.096
Triglidae	1.0	0.000	1.0	0.005	1.0	0.096
<i>Peristedion</i> sp.	1.0	0.000	1.0	0.005	1.0	0.096
Unid. fish	289.0	0.074	163.5	0.872	94.0	9.030
Unid. material	1.0	0.000	26.4	0.141	5.0	0.480
Empty					436.0	41.882
Total	388,912.0		18,739.9		1,041.0	

APPENDIX TABLE 2.—List of prey items and other ingested materials found in the stomachs of skip-jack tuna caught during Quarter I.

Prey items	Numbers		Volume		Occurrence	
	No.	%	mL	%	No.	%
Crustacea						
Mysidacea						
Eucopiidae	112.0	0.0076	9.3	0.253	8.0	2.658
Lophogastridae	19.0	0.013	1.5	0.041	2.0	0.664
Isopoda						
Flabellifera	1.0	0.001	0.1	0.003	1.0	0.332
Amphipoda						
Euphausiidae	49.0	0.033	2.3	0.063	4.0	1.329
<i>Euphausia similis</i>	144,070.0	97.624	2,125.9	57.878	34.0	11.296
Caridea						
Brachyura	1.0	0.001	0.5	0.014	1.0	0.332
Unid. megalops						
Unid. zoaea	80.0	0.054	22.6	0.615	17.0	5.648
Unid. Decapoda	549.0	0.372	28.6	0.779	19.0	6.312
Unid. Crustacea	4.0	0.003	0.1	0.003	1.0	0.332
Unid. Crustacea	47.0	0.032	8.3	0.226	13.0	4.319
Mollusca						
Gastropoda						
Pteropoda						
<i>Cavolina</i>	68.0	0.046	2.2	0.060	1.0	0.332
Cephalopoda						
Teuthoidea	2.0	0.001	2.0	0.054	2.0	0.664
Thysanoteuthidae	2.0	0.001	10.0	0.272	1.0	0.332
Ommastrephidae	5.0	0.003	1.1	0.030	2.0	0.664
Loliginidae	1.0	0.001	8.0	0.218	1.0	0.332
Octopoda						
Argonautidae						
<i>Argonauta</i> sp.	2.0	0.001	0.3	0.008	2.0	0.664
Insecta						
Coleoptera	1.0	0.001	1.0	0.027	1.0	0.332
Pisces						
Gonostomatidae						
<i>Maurollicus muelleri</i>	1,346.0	0.912	838.0	22.815	29.0	9.635
Belonidae	1.0	0.001	3.0	0.082	1.0	0.332
Holocentridae	3.0	0.002	4.0	0.109	1.0	0.332
Carangidae						
<i>Selene vomer</i>	6.0	0.004	9.0	0.245	6.0	1.993
Mullidae	2.0	0.001	8.0	0.218	1.0	0.332
Scombridae	15.0	0.010	1.5	0.041	2.0	0.664
<i>Auxis thazard</i>	427.0	0.289	189.7	5.165	21.0	6.977
<i>Scomber japonicus</i>	504.0	0.342	225.2	6.131	22.0	7.309
Gempylidae	76.0	0.051	48.5	1.320	11.0	3.654
Unid. Perciforms	9.0	0.006	7.0	0.191	5.0	1.661
Monacanthidae	13.0	0.009	9.5	0.259	8.0	2.658
Ostraciidae	1.0	0.001	0.5	0.014	1.0	0.332
Triglidae	1.0	0.001	1.0	0.027	1.0	0.332
<i>Peristedion</i> sp.	1.0	0.001	1.0	0.027	1.0	0.332
Unid. fish	137.0	0.093	76.5	2.083	35.0	11.628
Unid. material	1.0	0.001	26.3	0.716	4.0	1.329
Total	147,577.0		3,673.1		301.0	

APPENDIX TABLE 3.—List of prey items and other ingested materials found in the stomachs of skipjack tuna caught during Quarter II.

Prey items	Numbers		Volume		Occurrence	
	No.	%	mL	%	No.	%
Crustacea						
Stomatopoda	1.0	0.001	1.0	0.016	1.0	0.345
Mysidacea						
Eucopiidae	97.0	0.055	31.9	0.508	9.0	3.103
Lophogastridae	5.0	0.003	0.2	0.003	1.0	0.345
Isopoda						
Flabellifera	2.0	0.001	1.5	0.024	2.0	0.690
Amphipoda	2.0	0.001	1.0	0.016	1.0	0.345
Gammaridea	6.0	0.003	0.4	0.006	3.0	1.034
Euphausiidae	2.0	0.001	0.2	0.003	2.0	0.690
<i>Euphausia similis</i>	171,843.0	97.352	2,104.3	33.485	61.0	21.034
Caridea	1.0	0.001	0.8	0.013	1.0	0.345
Macrura						
Scyllaridae	1.0	0.001	0.2	0.003	1.0	0.345
Brachyura						
Unid. megalops	1.0	0.001	0.5	0.008	1.0	0.345
Unid. zoea	1.0	0.001	0.2	0.003	1.0	0.345
Unid. Decapoda	3.0	0.002	0.5	0.008	1.0	0.345
Unid. Crustacea	30.0	0.017	1.2	0.019	2.0	0.690
Mollusca						
Gastropoda						
Pteropoda						
<i>Cavolina</i> sp.	33.0	0.019	3.8	0.060	6.0	2.069
Cephalopoda						
Teuthoidea						
Ommastrephidae	6.0	0.003	8.5	0.135	5.0	1.724
Onychoteuthidae	13.0	0.007	6.0	0.095	2.0	0.690
Siphonophora						
Algalmidae	8.0	0.005	6.6	0.105	8.0	2.759
Pisces						
Gonostomatidae						
<i>Maurolicus muelleri</i>	4,287.0	2.429	3,548.0	56.458	38.0	13.103
Synodontidae	8.0	0.005	16.0	0.255	3.0	1.034
Myctophidae	24.0	0.014	61.3	0.975	4.0	1.379
Sygnathidae	1.0	0.001	1.0	0.016	1.0	0.345
Carangidae						
<i>Selene vomer</i>	2.0	0.001	8.0	0.127	2.0	0.690
<i>Decapterus punctatus</i>	2.0	0.001	46.0	0.732	2.0	0.690
<i>Caranx ruber</i>	70.0	0.040	360.0	5.729	17.0	5.862
Scombridae						
<i>Auxis thazard</i>	46.0	0.026	30.0	0.477	1.0	0.345
<i>Scomber japonicus</i>	8.0	0.005	6.0	0.095	2.0	0.690
Unid. Perciforms	1.0	0.001	12.0	0.191	1.0	0.345
Balistidae	1.0	0.001	5.0	0.080	1.0	0.345
Monacanthidae	4.0	0.002	4.1	0.065	3.0	1.034
Unid. fish	9.0	0.005	18.1	0.288	6.0	2.069
Total	176,518.0		6,284.3		290.0	

APPENDIX TABLE 4.—List of prey items and other ingested materials found in the stomachs of skipjack tuna caught during Quarter III.

Prey items	Numbers		Volume		Occurrence	
	No.	%	mL	%	No.	%
Crustacea						
Mysidacea						
Eucopiidae	10.0	0.046	0.8	0.020	4.0	1.843
Isopoda						
Flabellifera	2.0	0.009	0.3	0.007	2.0	0.922
Euphausiidae	88.0	0.401	1.4	0.034	9.0	4.147
<i>Euphausia</i> sp.	50.0	0.228	0.6	0.015	1.0	0.461
<i>Euphausia similis</i>	15,414.0	70.236	196.3	4.796	30.0	13.825
Unid. Crustacea	5.0	0.023	0.4	0.010	4.0	1.843
Mollusca						
Cephalopoda						
Teuthoidea	1.0	0.005	3.0	0.073	1.0	0.461
Pisces						
Gonostomatidae						
<i>Maurolicus muelleri</i>	6,239.0	28.429	3,289.2	80.369	74.0	34.101
Exocoetidae	2.0	0.009	2.0	0.049	2.0	0.922
<i>Exocoetus volitans</i>	1.0	0.005	56.0	1.368	1.0	0.461
Macrorhamphosidae	2.0	0.009	2.9	0.071	2.0	0.922
Carangidae	1.0	0.005	1.0	0.024	1.0	0.461
Mullidae	6.0	0.027	9.0	0.220	3.0	1.382
Scombridae						
<i>Scomber japonicus</i>	45.0	0.205	374.0	9.138	8.0	3.687
<i>Sarda sarda</i>	6.0	0.027	4.0	0.098	2.0	0.922
Trichiuridae	11.0	0.050	12.0	0.293	4.0	1.843
<i>Benthodesmus</i> sp.	19.0	0.087	80.9	1.977	8.0	3.687
Unid. Perciforms	4.0	0.018	35.0	0.855	3.0	1.382
Monacanthidae	1.0	0.005	1.0	0.024	1.0	0.461
Unid. fish	39.0	0.178	22.8	0.557	21.0	9.677
Total	21,946.0		4,092.6		217.0	

APPENDIX TABLE 5.—List of prey items and other ingested materials found in the stomachs of skipjack tuna caught during Quarter IV.

Prey items	Numbers		Volume		Occurrence	
	No.	%	mL	%	No.	%
Crustacea						
Stomatopoda	11.0	0.026	3.5	0.075	5.0	2.146
Mysidacea						
Eucopiidae	1.0	0.002	0.4	0.009	1.0	0.429
Isopoda						
Flabellifera	2.0	0.005	0.2	0.004	2.0	0.858
Amphipoda						
Gammaridea	10.0	0.023	4.7	0.100	7.0	3.004
Euphausiidae						
<i>Euphausia similis</i>	37,305.0	87.017	468.8	9.996	47.0	20.172
<i>Stylocheiron</i> sp.	1.0	0.002	0.3	0.006	1.0	0.429
Caridea	1.0	0.002	1.0	0.021	1.0	0.429
Macrura						
Scyllaridae						
Unid. Phyllosoma larvae	1.0	0.002	0.1	0.002	1.0	0.429
Brachyura	5.0	0.012	0.7	0.015	1.0	0.429
Portunidae	1.0	0.002	0.1	0.002	1.0	0.429
Unid. megalops	21.0	0.049	8.9	0.190	9.0	3.863
Unid. zoea	5.0	0.012	1.4	0.030	4.0	1.717
Unid. Crustacea	14.0	0.033	1.1	0.023	7.0	3.004
Mollusca						
Gastropoda						
Pteropoda						
Cavoliniidae	1.0	0.002	0.1	0.002	1.0	0.429
Cephalopoda						
Teuthoidea	1.0	0.002	21.0	0.448	1.0	0.429
Ommastrephidae	24.0	0.056	45.5	0.970	11.0	4.721
Loliginidae	1.0	0.002	2.5	0.053	1.0	0.429
Histiotteuthidae	1.0	0.002	1.0	0.021	1.0	0.429
Octopoda						
Argonautidae						
<i>Argonauta</i> sp.	18.0	0.042	75.6	1.612	9.0	3.863
Unid. Cephalopoda	4.0	0.009	1.3	0.028	3.0	1.288
Insecta						
Coleoptera	1.0	0.002	1.0	0.021	1.0	0.429
Siphonophora	1.0	0.002	0.9	0.019	1.0	0.429
Pisces						
Gonostomatidae						
<i>Maurolicus muelleri</i>	1,566.0	3.653	944.1	20.130	40.0	17.167
Paralepididae	1.0	0.002	0.5	0.011	1.0	0.429
Myctophidae	19.0	0.044	1.0	0.021	1.0	0.429
Scomberesocidae						
<i>Scomberesox saurus</i>	8.0	0.019	105.0	2.239	6.0	2.575
Belonidae	1.0	0.002	2.0	0.043	1.0	0.429
Macrorhamphosidae	3.0	0.007	4.0	0.085	2.0	0.858
Holocentridae						
<i>Holocentrus</i> sp.	3.0	0.007	9.0	0.192	1.0	0.429
Mullidae	3.0	0.007	8.0	0.171	2.0	0.858
Scombridae	1.0	0.002	1.0	0.021	1.0	0.429
<i>Auxis thazard</i>	1.0	0.002	4.0	0.085	1.0	0.429
<i>Scomber japonicus</i>	917.0	2.139	373.5	7.964	45.0	19.313
<i>Sarda sarda</i>	75.0	0.175	123.0	2.623	6.0	2.575
Gempylidae	100.0	0.233	52.2	1.113	9.0	3.863
<i>Thyrstitops lepidopoides</i>	2,617.0	6.104	2,348.4	50.074	54.0	23.176
Unid. Perciforms	10.0	0.023	9.7	0.207	7.0	3.004
Monacanthidae	9.0	0.021	5.2	0.111	7.0	3.004
Molidae	1.0	0.001	0.5	0.014	1.0	0.332
<i>Ranzania</i> sp.	3.0	0.007	13.0	0.277	1.0	0.429
Unid. fish	104.0	0.243	46.1	0.983	32.0	13.734
Unid. material	0.0	0.000	0.1	0.002	1.0	0.429
Total	42,871.0		4,689.9		233.0	

APPENDIX TABLE 6.—Mean volumetric ratio of selected food items of skipjack tuna divided into 5 cm length groups for all months. Data are  $\bar{x} \pm SD$  with (*n*) in parentheses. Range is 0-100%.

Length cm ( <i>n</i> )	Other fish	Other crustaceans	<i>Euphausia similis</i>	<i>Maurollicus muelleri</i>	<i>Scomber japonicus</i>	<i>Thyrsitops lepidoides</i>
45.0-49.9(67)	9.51 ± 22.5	9.51 ± 25.4	42.50 ± 48.1	10.35 ± 29.5	8.57 ± 23.6	16.64 ± 36.4
50.0-54.9(155)	10.53 ± 27.7	12.62 ± 30.9	26.73 ± 43.6	13.99 ± 33.4	12.44 ± 29.5	20.05 ± 38.5
55.0-59.9(162)	24.81 ± 39.4	11.80 ± 29.5	20.40 ± 39.5	29.49 ± 43.6	5.62 ± 19.6	2.70 ± 14.2
60.0-64.9(147)	23.48 ± 39.2	8.03 ± 24.7	18.83 ± 36.5	42.90 ± 48.2	2.12 ± 12.2	—
65.0-69.9(55)	42.80 ± 47.6	12.43 ± 31.7	4.73 ± 18.7	32.18 ± 45.9	0.27 ± 2.0	—
70.0-74.9(13)	48.30 ± 48.1	9.88 ± 27.9	8.57 ± 21.9	23.36 ± 43.7	2.20 ± 79.2	—
75.0-79.9(4)	47.50 ± 55.0	27.50 ± 48.6	—	25.00 ± 50.0	—	—
Total (603)	18.80 ± 35.5	10.96 ± 28.6	22.22 ± 40.0	26.73 ± 42.8	6.24 ± 21.1	10.34 ± 27.9

APPENDIX TABLE 7.—Mean volumetric ratio of selected food items of skipjack tuna divided into 5 cm length groups for Quarter I. Data are  $\bar{x} \pm SD$  with (*n*) in parentheses. Range is 0-100%.

Length cm ( <i>n</i> )	Other fish	Other crustaceans	<i>Euphausia similis</i>	<i>Maurollicus muelleri</i>	<i>Scomber japonicus</i>
45.0-49.9(12)	28.70 ± 33.4	35.15 ± 42.5	9.18 ± 28.7	7.48 ± 25.9	13.89 ± 38.4
50.0-54.9(53)	19.87 ± 36.8	29.64 ± 43.5	24.48 ± 43.3	6.09 ± 19.6	16.12 ± 33.5
55.0-59.9(45)	30.23 ± 40.9	17.69 ± 33.9	20.81 ± 38.9	22.96 ± 38.1	7.98 ± 25.2
60.0-64.9(36)	34.79 ± 44.1	16.96 ± 35.4	20.14 ± 38.9	20.92 ± 40.1	19.84 ± 46.5
65.0-69.9(4)	48.61 ± 56.2	28.24 ± 47.9	—	—	3.71 ± 7.4
70.0-74.9(3)	91.67 ± 14.4	8.33 ± 14.4	—	—	—
75.0-79.9(2)	—	—	—	—	—
Total (155)	29.55 ± 41.0	23.47 ± 38.9	19.80 ± 38.9	14.18 ± 32.1	10.08 ± 27.3

APPENDIX TABLE 8.—Mean volumetric ratio of selected food items of skipjack tuna divided into 5 cm length groups for Quarter II. Data are  $\bar{x} \pm SD$  with (*n*) in parentheses. Range is 0-100%.

Length cm ( <i>n</i> )	Other fish	Other crustaceans	<i>Euphausia similis</i>	<i>Maurollicus muelleri</i>	<i>Scomber japonicus</i>
45.0-49.9(26)	1.65 ± 8.4	5.00 ± 20.3	76.92 ± 43.0	15.38 ± 36.8	—
50.0-54.9(12)	5.82 ± 11.5	14.72 ± 33.0	65.71 ± 48.6	—	—
55.0-59.9(35)	20.89 ± 38.7	18.13 ± 36.4	35.65 ± 49.9	14.71 ± 33.9	0.14 ± 0.80
60.0-64.9(45)	16.33 ± 36.2	4.67 ± 18.5	28.92 ± 45.7	45.54 ± 49.7	0.32 ± 2.1
65.0-69.9(23)	54.07 ± 49.1	—	4.49 ± 20.8	30.29 ± 46.8	—
Total (141)	20.02 ± 38.1	8.16 ± 25.2	38.32 ± 48.6	25.96 ± 43.3	0.14 ± 1.3

APPENDIX TABLE 9.—Mean volumetric ratio of selected food items of skipjack tuna divided into 5 cm length groups for Quarter III. Data are  $\bar{x} \pm SD$  with (*n*) in parentheses. Range is 0-100%.

Length cm ( <i>n</i> )	Other fish	Other crustaceans	<i>Euphausia similis</i>	<i>Maurollicus muelleri</i>	<i>Scomber japonicus</i>
45.0-49.9(4)	25.81 ± 49.5	—	25.00 ± 50.0	24.19 ± 48.4	25.00 ± 50.0
50.0-54.9(27)	11.17 ± 32.0	1.24 ± 6.4	11.21 ± 32.0	61.56 ± 48.5	14.81 ± 36.2
55.0-59.9(36)	24.88 ± 41.3	9.22 ± 27.9	3.67 ± 16.2	59.05 ± 47.0	3.17 ± 16.8
60.0-64.9(31)	24.09 ± 40.5	3.39 ± 17.9	16.51 ± 29.9	53.76 ± 46.6	2.26 ± 12.6
65.0-69.9(17)	31.80 ± 46.4	17.65 ± 39.3	3.89 ± 9.8	46.67 ± 48.8	—
70.0-74.9(5)	31.27 ± 45.5	—	8.00 ± 17.9	60.73 ± 53.8	—
Total (120)	22.87 ± 40.1	6.42 ± 23.6	9.6 ± 25.5	55.40 ± 47.39	5.70 ± 22.7

APPENDIX TABLE 10.—Mean volumetric ratio of selected food items of skipjack tuna divided into 5 cm length groups for Quarter IV. Data are  $\bar{x} \pm SD$  with (n) in parentheses. Range is 0-100%.

Length cm (n)	Other fish	Other crustaceans	<i>Euphausia similis</i>	<i>Maurolicus muelleri</i>	<i>Scomber japonicus</i>	<i>Thyrsitops lepidopoides</i>
45.0-49.9(25)	5.86 ± 13.8	3.43 ± 11.0	25.49 ± 39.6	4.26 ± 16.9	12.30 ± 25.1	44.60 ± 48.4
50.0-54.9(63)	3.30 ± 13.4	2.77 ± 13.0	27.84 ± 43.4	2.91 ± 16.3	10.69 ± 25.1	49.33 ± 47.0
55.0-59.9(46)	22.45 ± 37.5	3.25 ± 15.3	21.48 ± 40.2	24.01 ± 42.9	9.40 ± 22.5	9.49 ± 25.7
60.0-64.9(35)	20.51 ± 35.4	7.29 ± 22.1	6.55 ± 19.5	52.48 ± 49.9	1.71 ± 85.6	—
65.0-69.9(11)	34.11 ± 44.1	24.59 ± 40.2	8.26 ± 27.4	25.45 ± 43.9	—	—
70.0-74.9(5)	39.31 ± 53.8	20.69 ± 44.4	14.29 ± 31.9	—	5.71 ± 12.8	—
75.0-79.9(2)	45.00 ± 63.6	5.00 ± 7.1	—	50.0 ± 70.7	—	—
Total (187)	14.80 ± 16.5	5.6 ± 19.5	29.17 ± 37.8	19.31 ± 38.9	8.03 ± 21.2	24.91 ± 27.7